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Evaluation of LLNL BSL-3 Maximum Credible Event Potential Consequence to the General Population and Surrounding Environment

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Executive Summary

The purpose of this evaluation is to establish reproducibility of the analysis and consequence results to the general population and surrounding environment in the LLNL Biosafety Level 3 Facility Environmental Assessment (LLNL 2008).

An evaluation by the National Research Council (NRC) of the health and safety risks associated with the United States Army Medical Research Institute of Infectious Diseases (USAMRIID) at Fort Detrick, Maryland (NRC 2010) called into question aspects of the Maximum Credible Event (MCE) scenario for the Final Environmental Impact Statement (EIS) (DA 1989). Specifically, it was the conclusion of the NRC review committee that analysis of the MCE aerosol dispersal risk was incomplete and not reproducible. The NRC's evaluation of the USAMRIID EIS is relevant as its MCE scenario and analysis is developed as a bounding accident event in DOE/EA-1442R, the Final Revised Environmental Assessment (EA) for The Proposed Construction and Operation of a Biosafety Level (BSL) 3 Facility at Lawrence Livermore National Laboratory, Livermore, California, Appendix B, Section B.3 Accidents.

In the referenced DA MCE analysis, a number of parameters applied within the atmospheric dispersion model were not explicitly stated. Conservative assumptions consistent with the postulated release scenario and with Environmental Protection Agency (EPA) guidance for offsite consequence analysis (EPA 2009) are applied as needed to model the analysis.

Additionally, in the referenced analysis, the potential consequence to the general public was evaluated using a closed-source Gaussian plume-dispersion air model, the Hazard Prediction and Assessment Capability (HPAC) software package developed by the Defense Threat Reduction Agency (DTRA). This evaluation utilizes the Hotspot Health Physics Code (HS 2009), a DOE-developed, publicly accessible Gaussian plume-dispersion model to calculate Respirable Time-Integrated Air Concentration (χ) values. From this, dose concentration and exposure to receptors for the postulated MCE scenario are estimated.

The conclusions of this evaluation are:

- The USAMRDC PEIS MCE consequence estimates for the general public and surrounding public may be reproduced using public-accessible Gaussian plume-dispersion model and conservative modeling assumptions consistent with the accident scenario where such assumptions are not stated.
- Potential consequences to the public for the LLNL BSL-3 facility for an event similar to that postulated in the USAMRDC PEIS MCE would be far below those estimated in the DA consequence analysis.

1.0 Introduction

The purpose of this evaluation is to establish reproducibility of the analysis and consequence results to the general population and surrounding environment in the LLNL Biosafety Level 3 Facility Environmental Assessment (LLNL 2008).

An evaluation by the National Research Council (NRC) of the health and safety risks associated with the United States Army Medical Research Institute of Infectious Diseases (USAMRIID) at Fort Detrick, Maryland (NRC 2010) called into question aspects of the Maximum Credible Event (MCE) scenario for the Final Environmental Impact Statement (EIS) (DA 1989). Specifically, it was the conclusion of the NRC review committee that analysis of the MCE aerosol dispersal risk was incomplete and not reproducible. The NRC's evaluation of the USAMRIID EIS is relevant as its MCE scenario and analysis is developed as a bounding accident event in DOE/EA-1442R, the Final Revised Environmental Assessment (EA) for The Proposed Construction and Operation of a Biosafety Level (BSL) 3 Facility at Lawrence Livermore National Laboratory, Livermore, California, Appendix B, Section B.3 Accidents.

In the referenced DA MCE analysis, a number of parameters applied within the atmospheric dispersion model were not explicitly stated. In this evaluation, conservative assumptions consistent with the postulated release scenario and with Environmental Protection Agency (EPA) guidance for offsite consequence analysis (EPA 2009) are applied as needed to model the postulated release.

Additionally, in the referenced analysis, the potential consequence to the general public was evaluated using a closed-source Gaussian plume-dispersion air model, the Hazard Prediction and Assessment Capability (HPAC) software package developed by the Defense Threat Reduction Agency (DTRA). This evaluation utilizes the Hotspot Health Physics Code (HS 2009), a DOE-developed, publicly accessible Gaussian plume-dispersion model to calculate Respirable Time-Integrated Air Concentration (χ) values. From this, dose concentration and exposure to receptors for the postulated MCE scenario are estimated.

Hotspot was developed by DOE as a tool for performing radiological event atmospheric dispersion consequence analysis. It is a companion dispersion model for the National Atmospheric Release Advisory Center (NARAC), which provides tools and services to the Federal Government that map the probable spread of hazardous material accidentally or intentionally released into the atmosphere. Hotspot is currently being evaluated for inclusion as part of the DOE Safety Analysis Tool Chest for performance of Nuclear Safety Analysis calculations.

While designed to model radiological atmospheric releases, Hotspot like the DTRA HPAC model, EPA/NOAA's ALOHA code and others is fundamentally a Gaussian plume-dispersion air model. Each of these models may be applied to calculate the relationship between the amounts of respirable material of concern released (source term) to that which a receptor at a (specified distance) may be exposed. This relationship is referred to as the atmospheric dispersion coefficient (χ/Q [s/m^3]. Through the use of Hotspot's "mixture" feature, χ may be directly predicted for particulate releases, including prediction of release depletion (in this case organism die-off rate) - once placed in terms of a "half-life."

This evaluation is developed as follows:

1. Introduction
2. Background – The USAMRDC PEIS MCE Scenario as presented in the LLNL BSL-3 Facility EA
3. Resolution of Apparent Inconsistent Analysis Value
4. Source Term Development
5. Dispersion analysis parameters – Including proposed values for data and assumptions not explicitly specified in the DA's atmospheric dispersion analysis

6. Reproduction of the DA’s dispersion analysis utilizing Hotspot
7. Conclusions

2.0 Background - USAMRDC PEIS MCE Scenario

This section presents USAMRIID PEIS MCE scenario in order to provide background for evaluation developed in later sections. The dispersion analysis developed later in this document seeks to confirm the results derived in the USAMRIID PEIS MCE scenario through application of the data and parameters within a publicly accessible Gaussian plume model, the Hotspot Health Physics Code.

No evaluation of the USAMRIID PEIS MCE scenario is performed in this section.

2.1. USAMRIID PEIS MCE Scenario Description

The MCE bioagent accident from the PEIS (DA 1989), Appendix A9 is presented in the LLNL BSL-3 Facility EA as follows:

Initial conditions:

- A typical BSL-3 equivalent laboratory exists at United States Army Medical Research Institute of Infectious Diseases (USAMRIID) and is designed to exceed Centers for Disease Control (CDC) guidelines.
- A centrifuge, the key piece of equipment in this scenario, is in a room and not in a biological safety cabinet (BSC).
- The size of the room is 1,080 ft^3 (30,240 liters), but since the room is under negative pressure and air flow is continuous, the volume of the duct from the room leading to the filter is also included 608 ft^3 (17,024 liters) for a total volume of 1,688 ft^3 (47,264 liters).
- The BSL-3 equivalent laboratory centrifuge room exhausts air via two filters in series, which are conservatively estimated to have 95 percent particulate removal efficiency, and air then exits through a roof stack.
- The only microorganism handled in the laboratory is a Rickettsial organism, *Coxiella burnetii*, which causes Q-fever, this organism is hardy and withstands laboratory manipulation with little or no loss in viability, is highly stable in aerosols and dies at a rate of about one percent per minute over a wide range of humidities (30 to 85 percent relative humidity) and temperature (0 to 30^{o}C). It is extremely infectious in a small particle aerosol.
- A single worker is working with one liter of *Coxiella burnetii* slurry.
- The worker places 165 milliliters of slurry into each of six 250-milliliter polypropylene centrifuge tubes **AND** fails to insert O-rings or tighten the centrifuge caps which are screw-on.

Accident scenario:

- The centrifuge is turned on at 10,000 revolutions per minute for 30 minutes
- All six tubes leak;
  - *Some slurry leaks into the rotor.*
  - *Some slurry leaks into centrifuge compartment.*
  - *Most of the slurry remains in the tubes.*
  - *Most of the slurry that leaked into covered rotor is not aerosoloized (99 percent).*
  - *Only a fraction of the slurry that leaked into the centrifuge cabinet is aerosolized and 90 percent of that settles as droplets inside the chamber.*
- A few minutes after the centrifuge stops, the worker opens the centrifuge and reaches in to remove the rotor;
  - *He notices leak. - He gets assistance of two co-workers to help him manage the spill.*
  - *Four more workers enter the laboratory not knowing of the accident.*

  - *All seven workers may have been exposed to a dose of organisms sufficient to cause infection in unimmunized individuals.*
- The slurry is thixotropic (much like egg white) but due to centrifuging has a reduced viscosity (20 to 25 centipoise) containing about 20 percent dry solids.
- The percent aerosol recovery (aerosol efficiency is defined as the number of infectious doses of *Coxiella burnetii* rendered airborne in a one- to five-micron particle size) representing the maximum infectivity for man is determined to conservatively be 0.1 percent.

Result to the Workers:

- The accident immediately produces 9.9×10^9 airborne human infective doses at a 50 percent rate for contracting the disease (HID_{50}) contained in a 3x3x3-foot area above and around the centrifuge (756 liters).
- There are 1.3×10^3 HID_{50} per liter of air in the seconds after the lid was opened.
- The centrifuge operator, excited by the accident, was breathing 15 liters of air per minute and was in the confined aerosol for no more than 5 minutes and could have inhaled about 100,000 HID_{50}.
- The two co-workers coming to the operator's assistance were exposed to only a slightly less dose than the centrifuge operator.
- The other four workers were exposed for less than 1 minute to the aerosol after it was dispersed in the room and are unlikely to have been exposed to more than 100 to 300 HID_{50}.

Result to the General Population and Surrounding Environment:

The result to the general public was evaluated using a simple Gaussian plume-dispersion air model. In this type of model the downwind distance that a given concentration of microorganisms would travel is a direct function of the emission rate and an inverse function of the lateral and vertical dispersion and wind speed. Higher rates of emission result in greater downwind distances for a given concentration. Similarly, lower lateral dispersion, vertical dispersion, or wind speed result in greater downwind concentrations. Downwind concentration is decreased as a consequence of environmental degradation (e.g ultraviolet light). Modeling assumptions used were:

- The maximum number of aerosolized infectious doses presented to the filters is 9.9×10^5 HID_{50}.
- After passing the 95% efficient filters the accident releases 5×10^4 infectious doses.
- The release is a daytime event since that is when the work is done.
- The breathing rate is 15 L/min.
- The lung retention of respirable particles is determined to be one-half or less of the intake.
- A Pasquill stability class D is used which "is the most stable one which can occur during the day."
- The mixing layer depth is 100 m for stable conditions.
- Lateral and vertical dispersion coefficients used are 9.02 m and 6.5 m, respectively. (Chosen for open level-terrain which is more conservative)
- The wind speed is 4.5 mph.
- The quantity of human infective doses, by simple Gaussian plume dispersion models, is expected to be dissipated to:
  - *Less than 1 HID_{50} in 1 liter (L) of air at a distance of less than 2 m from the stack,*
  - *Less than 0.1 HID_{50} in 1 L of air at a distance of 16 m from the stack, and*

- *Less than 0.01 HID_{50} in 1 L of air at a distance of 38 m from the stack.*

Of the rickettsial agents, *Coxiella burnetii* probably represents the greatest risk of laboratory infection, according to the CDC. The organism is highly infectious and remarkably resistant to drying and environmental conditions. The infectious dose of virulent Phase I organisms in laboratory animals has been calculated to be as small as a single organism. The estimated HID (25-50) (inhalation) for Q fever is 10 organisms…Q fever is the second most commonly reported laboratory associated-infection (CDC 1999). The CDC and the WHO identify Q fever as a disease most commonly contracted occupationally by those working with livestock handling and processing, and those in laboratory and veterinary practice (CDC 2001b; WHO 1999).

Men who were previously vaccinated and then exposed to aerosols of 150 or 150,000 infectious doses of virulent *Coxiella burnetii* did not consistently become ill (Benenson 1959). Therefore, since the centrifuge operator would have been vaccinated as a requirement of employment, it is questionable whether he would contract the illness. Antibiotic treatment (doxycycline), soon after exposure, significantly decreases the chances of developing symptoms of the disease (Benenson 1959).

The DA conclusion for its MCE showed that the only worker to conceivably contract the illness as a consequence of the accident would be the centrifuge worker, and even that individual would likely not become ill.

3.0 Resolution of Apparent Inconsistent Analysis Value

The data and assumptions leading to the evaluation of the potential consequences to workers involved in the postulated USAMRDC PEIS MCE scenario contain informational gaps which make it difficult to establish the number of infective doses of *Coxiella burnetii* in terms of HID_{50} produced immediately by the postulated accident and subsequently presented to the laboratory exhaust filters. Further, there is an apparent inconsistency in the value as stated in bullet #1 of the analysis of consequences to workers and that applied in the analysis.

3.1. Resolution of Apparent Discrepancy in USAMRDC PEIS MCE Source Term Development for Results to Workers

The stated value of 9.9E9 HID_{50} in bullet #1 of the Result to the Workers analysis appears to be a typographical error. Taken in context, the number of infective doses of *Coxiella burnetii* immediately produced in the room by the accident should instead be 9.9E5 HID_{50}.

The stated value of 9.9E9 HID_{50} of *Coxiella burnetii* immediately produced by the accident in a 756 L volume immediately surrounding the just-opened centrifuge cannot be calculated using only the data and assumptions provided in the stated initial conditions and accident scenario description. Further, this value is inconsistent with subsequent analyses and it appears inconsistent with reasonable interpretation of the accident scenario (filling in the informational gaps with credible engineering assumptions).

3.1.1. Apparent Discrepant Value in Context with Subsequent Analyses

Immediate Infective Dose Concentration

The infective dose concentration produced in the 756 L air space surrounding the centrifuge immediately upon opening the centrifuge chamber lid is estimated in the analysis as 1.3E3 HID_{50}/L. This value may only be obtained if the number of infective doses of *Coxiella burnetii* immediately produced in the room by the accident is 9.9E5 HID_{50} vs. 9.9E9 HID_{50}.

$$(9.9E5\ HID_{50})/(756\ L) = 1.31E3\ HID_{50}/L$$

3.1.1.1. Consequence to Centrifuge Operator

The centrifuge operator's exposure is estimated in the scenario as up to 1E5 HID_{50} *Coxiella burnetii* breathing at a rate of 15 LPM for up to 5 minutes. This is consistent with the estimated dose concentration of 1.3E3 HID_{50}.

$$(1.3E3\ HID_{50}/L)(15L/minute)(5\ minutes) = 97{,}500\ HID_{50} \approx 1E5\ HID_{50}$$

As above, this value may only be obtained if the number of infective doses of *Coxiella burnetii* immediately produced in the room by the accident is 9.9E5 HID_{50} vs. 9.9E9 HID_{50}.

3.1.1.2. Consequence to Workers Unknowingly Entering Infectious Spill Area

The consequence to four workers unknowingly entering the area where the postulated accident has taken place is estimated at no more than 100 to 300 HID_{50} *Coxiella burnetii* with exposure duration of less than 1 minute to room air containing the aerosol dispersed into a volume of 47,264 L (including exhaust ducting).

$$(9.9E5\ HID_{50})/(47{,}264\ L) = 2.1E1\ HID_{50}/L$$

$$(2.1E1\ HID_{50}/L)(15L/minute)(<1\ minute) = <314\ HID_{50}$$

As above, this value may only be obtained if the number of infective doses of *Coxiella burnetii* immediately produced in the room by the accident is 9.9E5 HID_{50} vs. 9.9E9 HID_{50}.

3.1.1.3. Maximum Number of Aerosolized Infectious Doses Presented to Exhaust Filters

The number of aerosolized infectious doses presented to the exhaust filters must be consistent with the number of aerosolized infectious doses produced by the accident. The maximum number of aerosolized infectious doses presented to the exhaust filters is specified in the scenario analysis as 9.9E5 HID_{50}. This value is consistent with a number of infective doses of *Coxiella burnetii* immediately produced in the room by the accident of 9.9E5 HID_{50} (discounting depletion through inhalation by the centrifuge operator & the two co-workers which could reduce the number of infectious doses by up to 3E5 HID_{50}).

3.1.2. Application of Engineering Assumptions to Supplement Non-Specified Parameters

It is beyond the scope of this calculation to establish or dispute the unstated parameters and assumptions leading to any specified value for the number of infectious doses of *Coxiella burnetii* produced by the postulated accident scenario. The intent herein is only to determine which value (9.9E5 HID_{50} or 9.9E9 HID_{50} *Coxiella burnetii*) is more consistent with a reasonable, conservative interpretation of the postulated accident scenario.

3.1.2.1. Data Provided in Initial Conditions

- Typical BSL-3 equivalent laboratory
- Room volume = 1,080 ft^3 (30,240 liters)
- Total volume (room + ducting) = 1,688 ft^3 (47,264 L)
- Room air exhausted via filters having a combined, estimated efficiency of 95%
- Total material at risk = 1 L of *Coxiella burnetii* slurry
- 165 mL of slurry is placed in each of 6 centrifuge tubes
  - Volume of slurry in centrifuge = (6)(165 mL) = 990 mL slurry

3.1.2.2. Data Provided in Accident Scenario

- All six tubes leak. Volume of slurry involved in postulated accident =volume of slurry in centrifuge = 990 mL slurry.
- Most of the slurry remains in the tubes.
  - No specific value applied to quantity of slurry which leaked from centrifuge tubes.
- Some slurry leaks into the covered rotor; 1% of this is aerosolized.
  - No specific value applied to quantity of slurry which leaked onto rotor.
- Some slurry leaks into the centrifuge compartment; a fraction of this is aerosolized; 10% of this remains aerosolized – the rest settle as droplets inside the chamber.
  - No specific value applied to quantity of slurry which leaked into cabinet.
- The slurry contains 20% dry solids.
  - SG of solids or slurry not provided.
- The percent recovery (aerosol efficiency is defined as the number of infectious doses of *Coxiella burnetii* rendered airborne in a one-to-five micron particle size) representing the maximum infectivity for man is determined to conservatively be 0.1%.
  - Number of organisms per gram not provided.
  - Number of organisms per HID_{50} not provided.

3.1.2.3. Credible Engineering Assumptions Consistent with Postulated Accident Scenario

- Quantity of slurry which leaks from centrifuge tubes

  - The accident scenario postulates that "most" of the slurry remains in the tubes. The postulated accident cause is a by the operator failure to insert O-rings or tighten the centrifuge caps which are screw-on; neither catastrophic failure of tubes, nor loss of tube caps is postulated.
  - It would not be credible to attribute more than 1% to 10% of the slurry leaking past an improperly sealed centrifuge tube. It is assumed 10% of slurry leaks from tubes.

Quantity of slurry postulated as having leaked from tubes = (0.1)(990 mL) = 99 mL

- Quantity of slurry which leaks into centrifuge covered rotor and is aerosolized
  - The scenario postulates that "some" slurry leaks into the rotor, and that 1% of this is aerosolized.
  - It likely that substantially more slurry leaking past improperly sealed caps would vent out & into the centrifuge cabinet than into the covered rotor. From this it may credibly be assumed that 1% of the slurry leaking from the tubes leaks onto the rotor – with the remaining slurry leaking into the centrifuge cabinet.

  Quantity of slurry postulated as leaking into the covered rotor and being aerosolized =

  (99 mL)(0.01)(0.01) = 9.9E-3 mL

- Quantity of slurry which leaks into centrifuge compartment, is aerosolized, and does not settle out as droplets into the centrifuge chamber.
  - The scenario postulates that "some" slurry leaks into the centrifuge compartment, that a "fraction" of this is aerosolized, and that 10% of this remains aerosolized.
  - As it has been postulated above that 1% of the leaking slurry leaks into the rotor, the remaining 99% would end up in the centrifuge chamber.
  - As with the covered rotor, it would be credible to assume that 1% of the slurry leaking into the centrifuge cabinet becomes aerosolized.

  Quantity of slurry postulated as leaking into the centrifuge compartment and being aerosolized =

  (99 mL)(0.99)(0.01) = 0.98 mL

  Quantity of slurry in the centrifuge chamber remaining aerosolized =

  (0.98 mL)(0.1) = 9.8E-2 mL

- The total quantity of slurry which becomes aerosolized & which does not settle as droplets within the chamber.
  - This quantity is the sum of the slurry aerosolized within the covered rotor & the centrifuge cabinet.

  Total quantity of slurry aerosolized remaining aerosolized upon opening of centrifuge lid =
  (9.9E-3 mL) + (9.8E-2 mL) = 1.1E-1 mL
- Mass of dry solids
  - The slurry is described as thixotropic (much like egg white), with about 20% dry solids.
  - Sermum-albumin (crystalline) has a documented concentration by weight of 22%, with a solution density of 1.0647 g/cc (LI 1912). This appears consistent with the slurry description. Applying the serum-albumin solution density:

  Mass of dry solids = (1.1E-1 mL)(1.0647 g/cc)(0.20 g dry solids/1 g solution) = 2.3E-2 g aerosolized slurry solids

- Number of *Coxiella burnetii* aerosolized
  - o No relationship has been provided in the accident scenario data with respect to the number of *Coxiella burnetii* in a given amount of dry material.
  - o Conservatively applying, in this case, the upper estimate for the number of *B. anthracis* spores per gram estimated in the 2001 terrorist attack involving letters sent to the Senate, 2 g of dry material could contain up to 1E12 organisms (DHS 2008).

  Number of *Coxiella burnetii* aerosolized =

  (2.3E-2 g aerosolized solids)(1E12 organisms/2 g material) = 1.2E10 organisms

- Number of *Coxiella burnetii* aerosolized
  - o No relationship has been provided in the accident scenario information with respect to the number of *Coxiella burnetii* organisms representing airborne human infective doses at a 50% rate for contracting the disease.
  - o The CDC states that *Coxiella burnetii* probably presents the greatest risk of laboratory infection. The organism is highly infectious and remarkably resistant to drying and other environmental conditions. The estimated human infective dose (HID) with a 25 to 50 percent chance of contracting the disease through the inhalation route for Q fever is 10 organisms (CDC 1999).

  (1.2E10 organisms)(1 HID_{50}/10 organisms) = 1.2E9 HID_{50} aerosolized

- Number of respirable *Coxiella burnetii* HID_{50} aerosolized
  - o Per accident scenario data, the percent aerosol recovery (aerosol efficiency is defined as the number of infectious doses of *Coxiella burnetii* rendered airborne in a one- to five-micron particle size) representing the maximum infectivity for man is determined to conservatively be 0.1 percent.

  (1.2E9 HID_{50} aerosolized)(0.001 respirable /total aerosolized) = 1.2E6 HID_{50}

The above value of 1.2E6 HID_{50} *Coxiella burnetii* calculated using credible engineering assumptions where scenario data was insufficient or unavailable is consistent with the 9.9E5 HID_{50} value applied to the USAMRDC PEIS MCE scenario consequence analyses. As such, the value of 9.9E5 HID_{50} appears more consistent with a reasonable interpretation of the postulated accident scenario than the value of 9.9E9 HID_{50}.

3.1.3. Conclusion with Respect to the Apparent Discrepant Value in USAMRDC PEIS MCE Source Term Development for Results to Workers

The value for the number of infectious doses in the USAMRDC PEIS MCE must be 9.9E5 HID_{50} *Coxiella burnetii* rather than 9.9E9 HID_{50}. The above-calculated value of 1.2E6 HID_{50} infectious doses presented to the centrifuge room exhaust filters will be applied to confirmation analysis of the potential consequences to general population and the surrounding environment.

4.0 Source Term Development for Evaluation of Potential Consequences to the General Population and Surrounding Environment

Source Term (ST) is the amount of material (in this case *Coxiella burnetii* in terms of HID_{50}) released to the air. The airborne source term is typically estimated by the following five-component linear equation (DOE 1994):

ST = MAR x DR x AF x RF x LPF

Where:

ST = Source Term
MAR = Material-at-Risk
DR = Damage Ratio
AF = Airborne Fraction
RF = Respirable Fraction
LPF = Leak Path Factor

4.1. MCE Scenario Source Term Input and Assumptions for Evaluation of Potential Consequences to the General Population and Surrounding Environment

- The maximum number of aerosolized infectious doses presented to the exhaust filters is 1.26E6 HID_{50} *Coxiella burnetii.*
  - MAR x DR x AF = 1.26E6 HID_{50}
- The BSL-3 equivalent laboratory centrifuge room in which the postulated takes place is under negative pressure and air flow is continuous (all room air exhausts via the filter bank).
- The BSL-3 equivalent laboratory centrifuge room in which the postulated takes place exhausts via two filters in series which are conservatively estimated to have a 95% particulate removal efficiency, and then exits through a roof stack.
  - All but 5% (0.05) of the material is captured by the filters
  - LPF = 0.05
- The lung retention of respirable particles is determined to be one half or less of the intake.
  - RF ≤ 0.5

4.2. MCE Scenario Source Term for Evaluation of Potential Consequences to the General Population and Surrounding Environment

Release to environment through 95% filters:

Release = (1.26E6 HID_{50} *Coxiella burnetii*)(0.05) = <6.3E4 HID_{50} *Coxiella burnetii*

Source Term:

ST = (1.26E6 HID_{50} *Coxiella burnetii*)(0.05)(0.5) = <3E4 HID_{50} *Coxiella burnetii*

5.0 Analysis Parameters for Evaluation of Potential Consequences to the General Population and Surrounding Environment

5.1. Dispersion Model Assumptions and Input for Evaluation of Potential Consequences to the General Population and Surrounding Environment

5.1.1. MCE Scenario Assumptions and Input

- Release is a daytime event since that is when the work is done.
- Maximally exposed individual breathing rate (BR) is 15 L/min (2.5E-4 m^3/s).
- Pasquill stability class D is used - which is the most stable one which can occur during the day.
- Mixing layer depth is 100 m for stable conditions
    - Temperature inversion assumed @ 100 m.
- Lateral and vertical dispersion coefficients used are 9.02 m and 6.5 m respectively (chosen for open level-terrain which is more conservative.
    - It is noted here that the lateral dispersion coefficient (σ_y) and vertical dispersion coefficient (σ_z) are both functions of downwind distance (x), and may not be specified as fixed variables. The specified values for σ_y and σ_z are generally consistent with a downwind distance of 100 m for the specified stability class and terrain.
    - Pasquill stability class D and standard (rural / open) terrain will be selected in the dispersion model
- Wind speed is 4.5 mph (2.1 m/s)
    - The impact of wind speed is dependent upon the height at which the wind speed is measured. As this was not specified, a measurement height of 3 m is assumed.
- The only microorganism handled in the laboratory is a Rickettsial organism, *Coxiella burnetii*, which causes Q-fever, this organism is hardy and withstands laboratory manipulation with little or no loss in viability, is highly stable in aerosols and dies at a rate of about one percent per minute over a wide range of humidities (30 to 85 percent relative humidity) and temperature (0 to 30^{o}C). It is extremely infectious in a small particle aerosol.
    - Organism die-off rate is about 1%/minute. Organism retention rate = 99%/minute
    - The Hotspot Health Physics Code does not directly handle source term depletion as a function of time in terms die-off rate. It does, however, handle source term depletion as a function of time in terms of half-life ($t_{1/2}$).
    - $t_{1/2}$ = (1 minute)[ln(0.5)/ln(0.99)] = 70 minutes.
- Receptors of interest for MCE scenario are at 2 m, 16 m, and 38 m from the exhaust stack.
    - The dispersion coefficients (based upon Briggs formulas) are considered applicable from a downwind distance of 0.1 km to approximately 10 km – generally extended out to 20 or 30 km. Application of the dispersion coefficients is not recommended below 10 m (HS 2009B). Hotspot limits the minimum downwind distance to 10 m.
    - Of additional interest for LLNL are receptors at 100 m (Gaussian dispersion model minimum applicable downwind distance) and 810 m (LLNL BSL-3 facility distance to closest public receptor)

5.1.2. Necessary Assumptions and Input not Provided in DA Analysis, but Consistent with MCE Scenario

- No release height is specified in the scenario
    - EPA guidance for analysis of offsite consequences, Worst Case Release Scenario assumes a ground level release.

- A release height = 0.0 m is assumed.

- No receptor height is specified.
  - This is not a selectable feature in codes such as EPA/NOAA's ALOHA chemical dispersion analysis code. ALOHA does not account for any substantial upward or downward movement of a gas cloud in the atmosphere. By default, for other than an elevated release, the receptor is conservatively assumed to be at the same height as the release, i.e. at ground level (EPA 2007).
  - Though not explicitly stated, technical background for the EPA's guidance for analysis of offsite consequence presumes a ground level receptor height (EPA 1999, Appendix D).
  - A receptor height = 0.0 m is assumed.
- No deposition velocity (plume depletion factor, dry deposition) is specified.
  - The suggested deposition velocity for a filtered particulate release is 0.1 cm/s (DOE 2004)
  - A particle deposition velocity of 0.1 cm/s is assumed.
- No release duration or rate is specified.
  - Release duration is assumed to be the time required to complete one air exchange for the centrifuge room. As the room exhaust rate is not known, a conservative value of 900 standard cubic feet per minute (SCFM) is assumed [Note: the faster the material is released, the more concentrated the plume & the greater the exposure]. From the scenario initial conditions, the room volume is 1,080 ft^3.

Release duration (RD) = (1,080 ft^3)/(900 SCFM) = 1.2 minutes = Exposure Duration

6.0 Hotspot Code Output

Table 1 : Hotspot Output for MCE 2.5E4 HID_{50} Release

DISTANCE [Km]	χ/Q NORMALIZED ATMOSPHERIC DISPERSION COEFFICIENT [sec/m^3]	χ RESPIRABLE TIME-INTEGRATED AIR CONCENTRATION [HID_{50}-sec/m^3]	ARRIVAL TIME [hour:min]
0.016	2.10E-01	6.3E+03	<00:01
0.038	3.80E-02	1.1E+02	<00:01
0.100	5.60E-03	1.7E+02	<00:01
0.810	1.10E-04	3.4E+00	00:07

6.1. Mean Respirable Dose Concentration Result to the General Population and Surrounding Environment

The USAMRDC PEIS MCE presented consequence in terms of a mean dose concentration. This is calculated as:

$$DC = \chi/ED$$

Where:

DC = Mean dose concentration [HID_{50}/L]

χ = Respirable Time-Integrated Air Concentration [HID_{50}-sec/m^3]

ED = Exposure Duration

Table 2 : Mean Respirable Dose Concentration

DISTANCE [Km]	RESPIRABLE AIR CONCENTRATION [HID_{50}/m3]	RESPIRABLE AIR CONCENTRATION [HID_{50}/L]	ARRIVAL TIME [hour:min]
0.016	8.4E+01	8.4E-02	<00:01
0.038	1.5E+01	1.5E-02	<00:01
0.100	2.2E+00	2.2E-03	<00:01
0.810	4.5E-02	4.5E-05	00:07

As is shown above:

- The dose concentration calculated at 16 m of 0.084 HID_{50}/L is consistent with the dose concentration result at 16 m of <0.1 HID_{50}/L presented in the USAMRDC PEIS MCE.
- The dose concentration calculated at 38 m of 0.015 HID_{50}/L is consistent with the dose concentration result at 38 m of <0.01 HID_{50}/L presented in the USAMRDC PEIS MCE.
- It is further shown that the dose concentrations applicable to the nearest public receptor to the LLNL BSL-3 Facility would be 4.5E-05 HID_{50}/L.

6.2. Exposure to the General Population and Surrounding Environment

The USAMRDC PEIS MCE presented potential worker consequence in terms of an exposure or dose. It did not do so for potential public receptor consequence. The following provides an estimate for potential exposure to the public for the postulated MCE scenario.

$$\text{Exposure} = Q \times \text{BR} \times \chi/Q = \text{BR} \times \chi$$

Where:

Q = the source term [HID_{50}]

χ/Q = atmospheric dispersion coefficient at an evaluated receptor location for the assumed atmospheric condition

χ = Respirable Time-Integrated Air Concentration [HID_{50}-sec/m^3]

BR = Breathing Rate

Table 3 : Exposure to General Population and Surrounding Environment

DISTANCE [Km]	RESPIRABLE DOSE [HID_{50}]	ARRIVAL TIME [hour:min]
0.016	1.6E+00	<00:01
0.038	2.8-01	<00:01
0.100	4.2E-02	<00:01
0.810	84.E-04	00:07

As shown above:

- For the postulated accident, there would be sufficient respirable *Coxiella burnetii* at 16 meters from the exhaust stack to represent slightly greater than one airborne human infective dose at a 50 percent rate for contracting the disease. It is predicted that beyond 20 meters human receptors would receive less than one HID_{50}.
- As previously noted, per the CDC, the HID_{50} for *Coxiella burnetii* is 10 organisms. If the minimum infective dose (MID) is represented by a single organism, then it is predicted that human receptors at 100 m and beyond would receive well below the MID for the postulated accident scenario.

7.0 Conclusions

The conclusion of this evaluation is that the consequence estimates in the USAMRDC PEIS MCE and subsequently the LLNL BSL-3 EA may be reproduced using a public-accessible Gaussian plume-dispersion model and conservative modeling assumptions consistent with the accident scenario postulated in the EA. Also, the potential consequences to the public for the postulated accident would be far below the minimum infectious dose of one organism.

References:

CDC 1999: Centers for Disease Control and Prevention, *Biosafety in Microbiological and Biomedical Laboratories*, U.S. Department of Health and Human Services, Public Health Service, CDC and National Institutes of Health (NIH), Fourth Edition, Washington, DC (April 1999)

DA 1989: Department of the Army, U. S. Army Medical Research and Development Command (USAMRDC), *Final Programmatic Environmental Impact Statement; Biological Defense Research Program*," Fort Detrick, Frederick, MD (April 1989)

DHS 2008: U.S. Department of Homeland Security, *National Bio and Agro-Defense Facility, Final Environmental Impact Statement, Appendix E, Accidents Methodology*, (December 2008)

DOE 1994: Department of Energy, DOE-HDBK-94, *DOE Handbook, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear facilities, Volume I – Analysis of Experimental Data* (December 1994)

DOE 2004: Department of Energy, DOE-EH-4.2.1.4-*MACCS2-Code Guidance, MACCS2 Computer Code. Application Guidance for Documented Safety Analysis* (June 2004)

DOE 2008: DOE/EA-1442R, *Final Revised Environmental Assessment for the Proposed Construction and Operation of a Biosafety Level 3 Facility at Lawrence Livermore National Laboratory*, Livermore, California

EPA 1999: U.S. Environmental Protection Agency, EPA 550-B-99-009, *Risk Management Program Guidance for Offsite Consequence Analysis* (April 1999)

EPA 2009: U.S. Environmental Protection Agency, EPA 550-B-99-009, *Risk Management Program Guidance for Offsite Consequence Analysis* (March 2009)

EPA 2007: U.S. Environmental Protection Agency, *ALOHA User's Manual* (February 2007)

HS 2009: Lawrence Livermore National Laboratory, *Hotspot - Health Physics Codes, Version 2.07*, Steve Homman (March 2009)

HS 2009b: Lawrence Livermore National Laboratory, *Hotspot - Health Physics Codes, Version 2.07 User's Guide*, LLNL-TM-411345, Steve Homman (March 2009)

LI 1912: Lister Institute, *The Density and Solution Volume of Some Proteins*, Harriette Chick, Charles James Martin, (November 1912)

LLNL 2008: Lawrence Livermore National Laboratory, DOE/EA-1442R, *Final Revised Environmental Assessment for the Proposed Construction and Operation of a Biosafety Level 3 Facility at Lawrence Livermore National Laboratory, Livermore, CA* (January 2008)

NRC 2010: National Research Council of the National Academies , *Evaluation of the Health and Safety Risks of the New USAMRIID High Containment Facilities at Fort Detrick, Maryland*, Committee to Review the Health and Safety Risks of High Biocontainment Laboratories at Fort Detrick, Board on Life Sciences Division on Earth and Life Studies (pre-publication, 2010)